BALLISTIC RESISTANT PLATE AND METHOD FOR PRODUCING SAME

FIELD OF THE INVENTION

The present invention relates generally to devices for providing defense against bullets, shrapnel and the like. More specifically, the invention is in the field of personal protection against offensive ammunition.

BACKGROUND OF THE INVENTION

Ballistic resistant plates (BRPs), sometimes referred to as ballistic resistant armour plates, are used for defending against the effect of bullets and fragments of artillery ammunition and mines. BRPs used for such an end are typically laminated, composed of stacked laminae and covered at one face with ceramic plates. In **Fig. 1A** to which reference is now made, a schematic description of bullet **20** is shown, projected in the direction of arrow **22**, to eventually hit ballistic armour **24**. Ballistic armour **24** is a laminated body, made of juxtaposed laminae. In **Fig. 1B** to which reference is now made, a schematic description of a bullet is shown, wherein bullet **20** has already hit the armour, creating a bulge **42**. In the short event of bullet impingement and penetration, the

plies are separated locally, this phenomenon is referred to as local delamination. Thus, as schematically shown in the figure, lamina **44** has separated from lamina **46** by gap **48**, whereas lamina **46** has separated from lamina **50** by gap **52**. Lamina **54** is separated from lamina **56** only to a very small extent.

Local delamination is exhibited upon the impingement on and penetration of a projectile into a laminated composite ballistic armour. In the course of a delamination, a considerable proportion of the energy of the impinging projectile hitting the armour is dissipated. This phenomenon is taken advantage of in a laminated armour, however, in order to facilitate effective local delamination, the adhesion strength must neither be too weak or rigid nor too strong. A strong adhesion tends to inhibit delamination altogether while weak adhesion would promote loosening of the bonds between the plies without withdrawing energy from the impinging projectile.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A is a schematic cross sectional view describing a projectile reaching a ballistic composite plate as in the prior art;

Fig. 1B is a schematic cross sectional view describing a projectile hitting a laminated armour plate, creating local delamination as in the prior art;

Fig. 2 is a chart describing the sequence of steps carried out in preparing a laminated armour plate in accordance with the present invention;

Fig. 3 is a schematic cross section in a prepreg of the invention;

Fig. 4 is an enlarged view of the cross section in a prepreg of the invention;

Fig. 5 is a schematic cross section in a stack of prepregs of the invention;

Fig. 6A is a schematic top side view of an armour plate describing the arrangement of ceramic tiles on a face of an armour plate of the invention;

Fig. 6B is a schematic sectional view of an armour plate of the invention describing the arrangement of ceramic tiles in the mass of the elastomer on the face of the plate.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

In accordance with the present invention, a stack of pre - impregnated laminae is cured using pressure and heat to form a ballistic resistant plate (BRP). The procedure for preparing the BRP of the invention is described schematically in **Fig. 2** to which reference is now made. In step **60** pre - impregnated slabs, hereinafter referred to as prepregs, are prepared. In step **62** the prepregs are trimmed to fit – in a certain geometric dimension. In step **64** the prepregs are stacked and in step **66** the prepregs stack is cured using temperature and pressure.

Prepreg preparation

A prepreg in accordance with the present invention consists of a polyaramid fabric plate impregnated with an elastomer resin. The elastomer in accordance with the invention functions as a filler and binder, but does not necessarily interact chemically with the polyaramid fibers. The elastomer is impregnated for example by immersing the fabric in the liquefied form of the precursor of the elastomer, which is typically a dissolved or emulsified monomer. A typical solvent is xylene. The elastomer/solvent ratio effects the amount of elastomer deposited in the prepreg, and hence some of the ballistic and mechanical properties of the prepreg. By controlling the elastomer/solvent ratio a control of the delamination tendency of the armour plate can be achieved. To describe its structure, reference is made to **Fig. 3**, which is a schematic description of a prepreg **80** of the invention. In a front cross sectional view **82** of the prepreg, bundles **84** of the polyaramid fabric are shown, the bundles of the fabric are embedded in the semi – hardened matrix **86** of the non – cured

elastomer monomer. In **Fig. 4** to which reference is now made, an enlarged portion of the sectional view of the prepreg **80** is shown. Bundles **84** are composed of filaments, designated **88**. Matrix **86** fills the space between the upper **90**, and the lower **92** faces of the prepreg.

After impregnation, the solvent is evaporated, leaving the prepreg dried, non – sticky, and stiff enough to be easily handled.

Piling up a stack and curing the elastomer

After drying, the prepregs are trimmed to a specific size which determines the vertical dimensions of the stack. A stack of prepregs is described schematically in **Fig. 5** to which reference is now made. Prepreg **102** is laid over prepreg **104**, laid over prepreg **106**, and over **108**, respectively. The elastomer monomer now forms a continuum throughout the cross section of the stack.

Once the stack is formed, curing can take place, typically by applying temperature and pressure on the piled stack. The pressure can be applied by a mechanical means such as a press or isostatically by means of compressed gas in a closed chamber. Temperatures used in such curing are recommended supplied by the manufacturers of elastomer, and can also be found in various technical data publications regarding various curing techniques. Chloroprene is an exemplary elastomer precursor, known as Neoprene after curing. If rubber is used as an elastomer, vulcanization is applied as a curing method.

As a result of the curing process, (or vulcanization in the case of rubber) a laminated BRP plate is obtained, wherein a continuum of the elastomer spans the laminae between both faces of the BRP. In other words, in a cross

section of the BRP, the cured elastomer forms a continuum, in which polyaramid fabric layers are embedded.

Ceramic tile application

The use of elastomers in the preparation of a BRP lends itself to straightforward attachment of ceramic tiles on a face of the BRP. In a preferred embodiment of the invention, ceramic tiles are fixed to BRP using the same elastomer as the one used to prepare the BRP. In **Fig 6A** to which reference is now made, a part of an armour plate **120** of the invention is shown as viewed from the top side, in which ceramic tiles **122** are embedded in the elastomer **124** of the armour. A side view of the armour of the invention is shown in **Fig. 6B** to which reference is now made. Tiles **122** are shown embedded in the elastomer **124** at the top side of the armour plate.

Operational benefits of using an elastomer as a binder and filler in accordance with the present invention

Experiments prove that a BRP prepared in accordance with the present invention provides for extended durability as compared to other BRPs. A BRP prepared in accordance with the present invention is able to stand more rounds of ammunition shot at from the same distance other makes of BRPs were shot at. The extended durability of a BRP of the invention means that the product of the invention is able to provide protection for a user, against more rounds of ammunition shot at.